The Automated Satellite Data Processing System

MODIS Processing

The Automated Satellite Data Processing System: MODIS Processing

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Chapter 1. Introduction

MODIS is a MODerate resolution Imaging System on board the NASA's Terra and Aqua satellites. It is a whisk-broom type sensor that includes multiple resolutions (250m, 500m, and 1000m) and 36 bands that cover the visible, near-, short-, and long-infrared regions. This large coverage provides the simulatenous measurement of ocean color and sea surface temperatures.

MODIS Reception

MODIS is collected by the NASA.

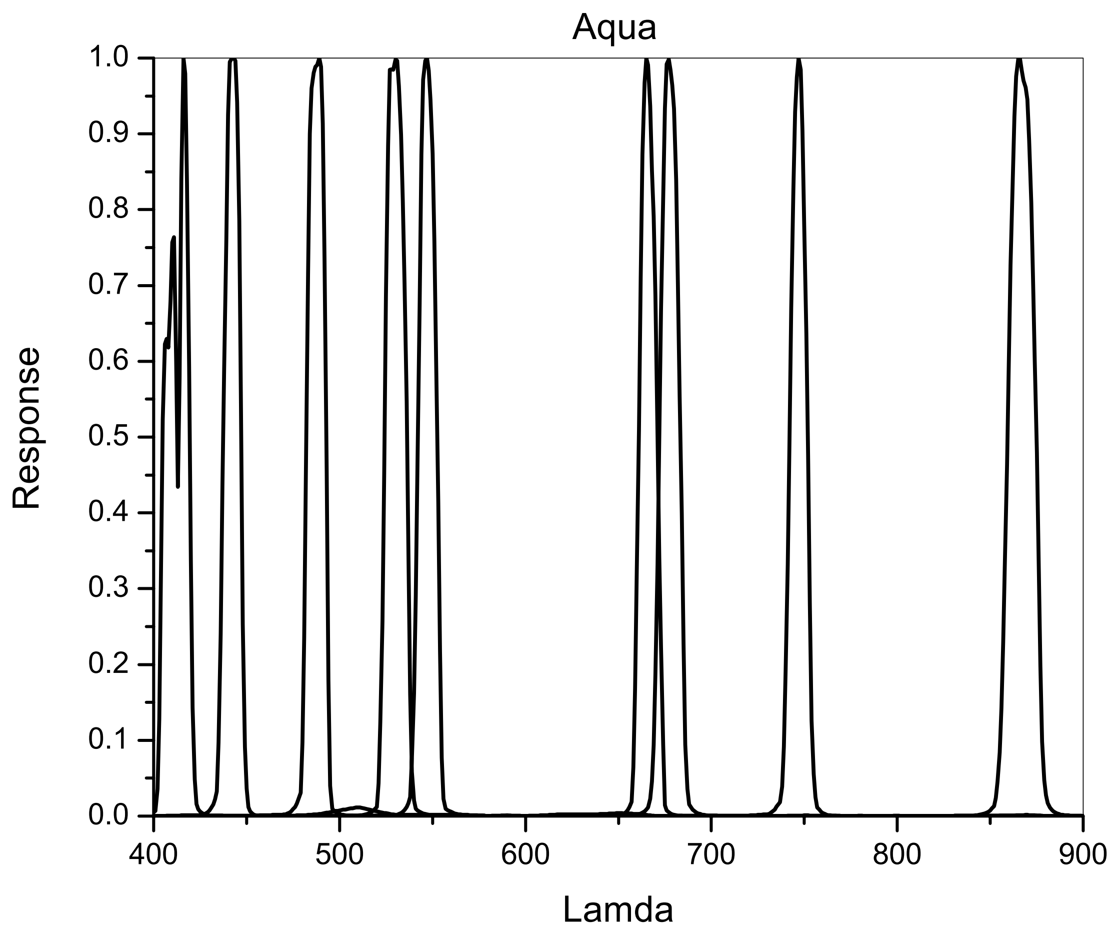
Chapter 2. MODIS Processing

The MODIS instrument has a very similar spectral suite as other ocean color satellites (as well as other temperature data). Therefore, it is processed using the same general methods described in the ocolor color processing documentation. This chapter will only discuss the deviations from general processing specific to MODIS.

Sensor Response

The SeaWiFS instrument consists of an optical scanner and an electronics module. Below is a listing of the central wavelengths and bandwidths for SeaWiFS.

Figure 2.1.



Rayleigh/Aerosol tables

These tables are provided in the `data/modis[a,t]/rayleigh` and `data/modis[a,t]/aerosol` directories. The Rayleigh tables are given for each band. The aerosol tables are generated based on the model selections. These tables were derived by NASA.

Sensor Tables

The sensor table `data/modis[t,a]/msl12_sensor_info.dat` contains values specific to the MODIS sensor. These include the values for F0, tau_r, water absorption and backscattering terms. For MODIS, these values were generated by convolving high-spectral resolution inputs.

For the F0, the `data/common/ThuillerF0.dat` file provides the solar irradiance spectra at 1nm. The convolution of that data with the spectral respsonse provided the values given for F0 in the table in the sensor table above.

Likewise, the Rayleigh optical thickness values were generated from the `data/common/taur.txt`. The water absorption values were convolved from the `data/common/water_spectra.dat` table. And the ozone absorption coefficient values were generated from `data/common/Nickolet_o3_abs.txt`.

Atmospheric Corrections

The vicarious calibration gains and offsets for MODIS were derived from NASA.

The out-of-band correction is applied to the MODIS data. The correction was derived from NASA.

The BRDF correction used by MODIS is identical to all the other sensors processed by l2gen.

Chapter 3. Products

MODIS Top-of-Atmosphere Products

The MODIS Top-of-Atmosphere products include the atmospheric properties of the total radiance at the sensor.

Products

Product	Description
Lt_*nnn*	calibrated TOA radiance at *nnn* nm
Ltir_*nnn*	calibrated TOA radiance at *nnn* nm
rhot_*nnn*	TOA reflectance at *nnn* nm
TLg_*nnn*	TOA glint radiance at *nnn* nm
glint_coeff	glint radiance normalized by solar irradiance
tLf_*nnn*	foam (white-cap) radiance at *nnn* nm
Lr_*nnn*	Rayleigh radiance at *nnn* nm
L_q_*nnn*	polarization radiance at *nnn* nm, q-component
L_u_*nnn*	polarization radiance at *nnn* nm, u-component
polcor_*nnn*	polarization correction at *nnn* nm
t_sol_*nnn*	Rayleigh-aerosol transmittance,sun to ground at *nnn* nm
t_sen_*nnn*	Rayleigh-aerosol transmit-tance,ground to sensor at *nnn* nm
t_oz_sol_*nnn*	ozone transmittance,sun to ground at *nnn* nm
t_oz_sen_*nnn*	ozone transmit-tance,ground to sensor at *nnn* nm
t_o2_*nnn*	total oxygen transmittance at *nnn* nm
t_h2o*nnn*	total water vaport transmittance at *nnn* nm
taua_*nnn*	aerosol optical depth at *nnn* nm
tau_*nnn*	same as taua_*nnn*
brdf_*nnn*	BRDF coefficient at *nnn* nm
La_*nnn*	aerosol radiance at *nnn* nm
Es_*nnn*	extra-terestrial surface irradiance at *nnn* nm

MODIS Atmospheric Correction Products

Geometery Products

La_*nnn*	aerosol radiance at *nnn* nm
aerindex	aerosol index
aer_model_min	minimum bounding aerosol model #
aer_model_max	maximum bounding aerosol model #
aer_model_ratio	model mixing ratio
aer_num_iter	number of aerosol iterations, NIR correction
epsilon	retreived epsilon used for model selection
eps_78	same as epsilon
angstrom_*nnn*	aerosol angstrom coefficents (*nnn*,865) nm
eps_*nnn*_*lll*	ratio of *nnn* to *lll* single-scattering aerosol radiances
rhom_*nnn*	water + aeorsol reflectance at *nnn* nm (MUMM)

MODIS Water Products

Geometery Products

rrs_*nnn*	remote sensing reflectance at *nnn* nm
nLw_*nnn*	normalized water-leaving radiance at *nnn* nm
Lw_*nnn*	water-leaving radiance at *nnn* nm
rhos_*nnn*	surface reflectance at *nnn* nm

MODIS Geometery Products

Geometery Products

Product	Description
pixnum	pixel number
detnum	detector number
mside	mirror side
latitudes	latitudes (-90.0 to 90.0)
longitudes	longitudes (-180.0 to 180.0)
solz	solar zenith angle
sola	solar azimuth angle
senz	satellite zenith angle
sena	satellite azimuth angle

MODIS Ancillary Data Properties

The following apparent optical properties

Product	Description
windspeed	magnitude of wind at 10 meters
zwind	zonal wind speed at 10 meters
mwind	meridional wind speed at 10 meters
windangle	wind direction at 10 meters
water_vapor	precipital water concentration
humidity	relative humidity
pressure	barometric pressure
ozone	ozone concentration
no2_tropo	tropospheric NO2
no2_strat	stratospheric NO2

MODIS Chlorophll-a Products

The chlorophyll-a product for MODIS uses the same general formula for chlorophyll-a calculations. However, due to the configuration of band spectra (no 510 nm channel), the algorithm is a 3-band ratio as opposed to the normal 4-band algorithm of other ocean color satelittes.

Product	Description
chl_oc2	chlorophyll-a concentration using OC2 algorithm
chl_oc3	chlorophyll-a concentration using OC3 algorithm
chl_oc4	chlorophyll-a concentration using OC4 algorithm
chlor_a	chlorophyll-a concentration using sensor-specific default
chl_stumpf	chlorophyll-a concentration using Stumpf's algorithm
chl_carder	chlorophyll-a concentration using Carder's algorithm

MODIS Apparent Optical Properties

The following apparent optical properties

Product	Description
Kd_532	diffuse attenuation at 532 nm using 490/555 ratio
K_length_532	diffuse attenuation at 532 nm using 443/555 ratio
Kd_*nnn*_lee	diffuse attenuation at *nnn* nm using Lee algorithm
Kd_490_morel	diffuse attenuation at 490 nm using Morel Eq8
Kd_490_morel_ok2	diffuse attenuation at 490 nm using Morel OK2
Kd_490_mueller	diffuse attenuation at 490 nm using Mueller
Kd_490_obpg	diffuse attenuation at 490 nm using OBPG
Kd_PAR_morel	diffuse attenuation (PAR) using Morel algorithm (1st optical depth)
Kd_PAR_lee	diffuse attenuation (PAR) using Lee algorithm (1st optical depth)

MODIS IOP Products

For the QAA product suite, the MODIS sensor has a 645 nm channel which is near the required 640 nm used to estimate the absorption at 555nm. The coefficients for xxx are uniquely derived.

qaa_opt
: A value of 1 (the default) indicates the use of the modeled 640nm channel,

qaa_adg_s
: Define the spectral slope parameter, s, to use in the QAA algorithm. Default is 0.015.

qaa_wave
: The sensor specific wavelengths for QAA. For MODIS, these are defined as [412,443,488,551,-1].

Product	Description
a_*nnn*_carder	total absorption at *nnn* nm using Carder algorithm
aph_*nnn*_carder	phytoplankton absorption at *nnn* nm using Carder algorithm
adg_*nnn*_carder	detris/gelbstuff absorption at *nnn* nm using Carder algorithm
bb_*nnn*_carder	backscatter at *nnn* nm using Carder algorithm
b_*nnn*_carder	total scattering at *nnn* nm using Carder algorithm
c_*nnn*_carder	beam attenuation at *nnn* nm using Carder algorithm
a_*nnn*_gsm01	total absorption at *nnn* nm using GSM01 algorithm
aph_*nnn*_gsm01	phytoplankton absorption at *nnn* nm using GSM01 algorithm
adg_*nnn*_gsm01	detris/gelbstuff absorption at *nnn* nm using GSM01 algorithm
bb_*nnn*_gsm01	backscatter at *nnn* nm using GSM01 algorithm
b_*nnn*_gsm01	total scattering at *nnn* nm using GSM01 algorithm
c_*nnn*_gsm01	beam attenuation at *nnn* nm using GSM01 algorithm
a_*nnn*_qaa	total absorption at *nnn* nm using QAA algorithm
aph_*nnn*_qaa	phytoplankton absorption at *nnn* nm using QAA algorithm
adg_*nnn*_qaa	detris/gelbstuff absorption at *nnn* nm using QAA algorithm
bb_*nnn*_qaa	backscatter at *nnn* nm using QAA algorithm
b_*nnn*_qaa	total scattering at *nnn* nm using

MODIS Water Mass ClassificationProducts

Water Mass

wmass	water mass classification using Gould algorithm
water_mass	water mass classification image using Gould algorithm
PIM_gould	particulate inorganic matter using Gould algorithm
POM_gould	particulate organic matter using Gould algorithm
TSS_gould	total suspened particles using Gould algorithm
aph_412_gould	phytoplankton absorption at 412 nm using Gould algorithm
asd_412_gould	sediment and detrital absorption at 412 nm using Gould algorithm
asd_412_gould	sediment and detrital absorption at 412 nm using Gould algorithm
ag_412_gould	gelbstuff absorption at 412 nm using Gould algorithm
ap_412_gould	particulate absorption at 412 nm using Gould algorithm
as_412_gould	sediment absorption at 412 nm using Gould algorithm

MODIS Sea Surface Temperature Properties

The following land properties

Product	Description
sst	sea surface temperature
sst4	sea surface temperature (4um)
qual_sst	quality indicator of sst
qual_sst4	quality indicator of sst4

MODIS Land Properties

The following land properties

Product	Description
ndvi	normalized difference vegetation index
evi	enhanced vegetation index
smoke	smoke index
height	terrain height

Name

modArea -- determine file extents of geographical area

modArea
`modArea` [-M *`mapFile`*] *`mapName inFile`*

Description

Determine the file extents (start/stop pixel/line) of a MODIS Level-1B file (still in sensor projection, etc.) that covers a map using the geolocation data in the file. It can handle the MOD03 or any of the MOD02 files.

ModArea begins by reading in the map from the mapFile. If the file can not be opened or the named map is not in the file, a diagnostic is printed and the program will exit.

Next, the input file is opened and the navigation information initialized. If unable to open the MODIS file or retrieve the navigation information from it, the program will print a diagnostic and exit.

Once the navigation has been set, **modArea** reads every point to detemine if that point falls within the desired map. From this, the smallest box that will cover the box will be determined. These file extents will be printed to the screen. If none of the latitude/longitude pairs fall in the map, then the message “No coverage” will be printed. If the file extents are the original input file, then the message will be “Complete coverage.”

In addition “No Water Coverage” is output if file does not cover any water pixels in the map.

Options

-a

Reduce data file extents by given sensor zenith angle.

-d

Debug output.

-h

Treat output (sample/lines*2) as HKM for MOD03 file.

-l

Don’t output start/stop line locations.

-m percent

Set a minimum coverage that the input data must cover the region of interest. Default value is 0.

-M mapFile

Use the given map file to find mapName. Defaults to $APS_DATA/maps.hdf.

-p

Don’t output start/stop pixel locations.

-q

Treat output (sample/lines*4) as QKM for MOD03 file.

-v

Make output verbose.

--help

Print out help and exit.

--version

Print out version and exit.

Environmental Variables

APS_DATA

The location of the APS data directory. Used to determine location of the default map file.

Examples

The first line shows what happens when then environment variable is not set. If not set, user must use -M to define location, unless the default file is in the current directory. The last shows the normal behavior.

```
$ modArea GulfOfMexico MOD021KM.P2003134.1140.NOAA
Map (GulfOfMexico) does not exist in file (maps.hdf).
$ modArea -M ~/aps_v3.1/data/maps.hdf GulfOfMexico MOD021KM.P2003134.1140.NOAA
unable open landmask file, not checking water coverage
No coverage
$ export APS_DATA=~/aps_v3.1/data
$ modArea GulfOfMexico MOD021KM.P2003134.1140.NOAA
No coverage
```

The next examples shows examples of regions that cover and do not cover the given regions of interest. It also shows examples of running the code on different inputs files.

```
$ modArea MissBight MOD03.A2002031.1535.003.2002034024442.hdf
No coverage
$ modArea PersianGulf MOD021KM.A2003133.0745.NOAA
747 1354 2 1157
$ modArea PersianGulf MOD03.A2003133.0745.NOAA
742 1354 1 1149
$ modArea PersianGulf MOD02HKM.A2003133.0745.NOAA
1484 2708 1 2298
$ modArea -h PersianGulf MOD03.A2003133.0745.NOAA
1484 2708 1 2298
$ modArea PersianGulf MOD02QKM.A2003133.0745.NOAA
2968 5416 1 4596
$ modArea -q PersianGulf MOD03.A2003133.0745.NOAA
2968 5416 1 4596
```

These examples show a file that is completely over land, and how changing the angle reduces the coverage of the data.

```
$ modArea PersianGulf MOD02HKM.A2003129.0805.NOAA
2350 2708 3634 4042 No Water Coverage
$ modArea ArabianSea MOD03.A2003133.0745.NOAA
678 1354 508 2030
$ modArea -a 60 ArabianSea MOD03.A2003133.0745.NOAA
678 1310 557 2030
$ modArea -a 55 ArabianSea MOD03.A2003133.0745.NOAA
678 1264 594 2030
```

As the angle is reduced, the percent coverage of the region of interest is also reduced. So, as you can see if we set a minimum amount of coverage, we eventually get “No Coverage”.

```
$ modArea -m 15 -a 55 MOD03.A2003133.0745.NOAA
678 1264 594 2030
$ modArea -m 15 -a 50 MOD03.A2003133.0745.NOAA
No coverage
```

If a problem is suspected, then use the -v (verbose) option to output more information.

```
$ modArea -v GulfOfMexico MOD03.A2002031.1535.003.2002034024442.hdf
Using Default MapFile ($APS_DATA/maps.hdf)
Initializing Map GulfOfMexico (From File /home/martinol/aps_v3.1/data/maps.hdf)
Reading Navigation Data MOD03.A2002031.1535.003.2002034024442.hdf ... done
Projecting Navigation Data to GulfOfMexico ... done
Scaning Navigation for file limits ... done
Percent Coverage/Miniumum = 0.04747047/0
limits of input file
sinpix = 1
einpix = 25
sinlin = 1
einlin = 11
limits of image map
soupix = 1872
eoupix = 2010
soulin = 1796
eoulin = 1810
size  = 2430 x 1810
1 26 1 12
Normal Completion!
```

Name

modInfo -- query information about a MODIS Level-1B file

modInfo
`modInfo [option] modFile`

Description

This program is used to dump information about a MODIS data file. With no options the program will print out a series of parameters. A single parameter can obtained using a selected option. The options are succint as they were designed with shell scripting in mind.

Options

-year
: 4-digit year of input file.

-doy
: 3-digit day of year of input file.

-month
: 3-character month of input file. Months are ‘jan’, ‘feb’, ‘mar’, ‘apr’, ‘may’, ‘jun’, ‘jul’, ‘aug’, ‘sep’, ‘oct’, ‘nov’, ‘dec’

-time
: 6-digit time (HHMMSS) of input file.

-hour
: 2-digit hour (HHMMSS) of input file.

-min
: 2-digit min (MM) of input file.

-sec
: 2-digit second (SS) of input file.

-start_time
: start time of input file.

-end_time
: end time of input file.

-platform
: Platform of MODIS file (1=Terra, 2=Aqua)

-version
: Major component of PGE version of file.

--version
: Print out version and exit.

Examples

```
$ modInfo MOD021KM.A2001337.0340.003.2001339033031.hdf
Filename:      MOD021KM.A2001337.0340.003.2001339033031.hdf
Starting Time:  12/03/2001 03:40, 337
Ending Time:    12/03/2001 03:45, 337
$ modInfo -year MOD021KM.A2001337.0340.003.2001339033031.hdf
2002
$
```

Here is how a Bourne shell script function might use **modInfo** to set the name of the output files from the input file:

```
set_name()
{
   yr=‘modInfo -year $1‘
   jday=‘modInfo -doy $1‘
   time=‘modInfo -time $1‘
   file=MODAM$yr$jday$time.L1A
}
```